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# Adoption and income effects of agricultural extension in northern Ghana

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## ABSTRACT

Relying on cross-sectional data from 300 smallholder rice farmers, the study examined the effects of agricultural extension on improved rice variety adoption and farm income in northern Ghana. A recursive bivariate probit (RBP)<sup>1</sup> model was used to assess the effect of agricultural extension on adoption while regression with endogenous treatment effect model (RETEM)<sup>2</sup> was adopted to evaluate the effect of agricultural extension on farm income. The results indicate a statistically significant effect of agricultural extension on both adoption and farm income. According to the RETEM model, farm income of participants in agricultural extension increased by GH¢916 relative to non-participants. The study highlights significant factors affecting adoption and farm income and provides insight into measures to enhance technology adoption and farm income among smallholder agrarian households in Ghana and other developing countries.

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## Introduction

Agriculture is central to Africa's socio-economic development, and Ghana is no exception. The agricultural sector in Ghana contributed 20.3% to gross domestic product (GDP) in 2015 [1] and 22.6% in 2016 [2] with over 60% of the population obtaining their livelihood from the sector [3]. The agricultural sector is dominated by smallholder farm families employing rudimentary technologies in production. Consequently, yield of most crops is below achievable levels. For example, the yield of major staple crops like maize and rice is below half the economically achievable level [4]. Several factors account for the low yield in Ghana and these include the use of rudimentary technologies in production, reliance on rainfall for production, low adoption of modern production technologies such as improved seeds, irrigation, chemical fertilizers, and mechanization. Other factors include low level of education among smallholder farmers, which has implication for human capital development and ability to take advantage of opportunities and production technologies to enhance farm performance.

*Abbreviations:* RBP, Recursive bivariate probit; RETEM, Regression with endogenous treatment effect model; UES, Unified Extension System; T&V, Training and Visit; MoFA, Ministry of Food and Agriculture; ATE, Average treatment effect.

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<sup>1</sup> RBP – Recursive bivariate probit.

<sup>2</sup> RETEM – Regression with endogenous treatment effect model.

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As shown by Gatzweiler and von Braun [5], technological innovations enhance agricultural productivity thereby improving the welfare of rural farmers. However, technological innovations may not benefit farmers if such innovations are not made available to them. Most smallholder farmers live in rural communities and rely on public extension services for information on modern production practices and technologies. This calls for an efficient agricultural extension system for information and technology transfer to smallholder farmers to ensure increased productivity and farm incomes. It is in the light of the foregoing that the government of Ghana has given impetus to agricultural extension delivery to ensure that information on modern production technologies is disseminated to farmers to enhance adoption, which is expected to increase productivity and farm incomes. Agricultural extension delivery in Ghana is mainly a public service, and the goal is to ensure effective dissemination of information on production activities and modern technologies to farmers.

Extension service delivery in most developing countries is associated with challenges such as improper design of extension programs and messages. Even where agricultural extension services are available, many smallholders may not make use of them because they have not been designed to meet their specific needs. As a result, many smallholders do not make the effort to seek extension services [6,7]. According to Agbarevo [8], the low use of technologies and extension services is not the result of farmers' unwillingness to use them but the result of poor extension service delivery methods, inadequate personnel and lack of logistics and materials.

As a result of the poor performance of many public extension services, there is a gradual shift in some countries towards privatization of extension services, or the shift of responsibility to farmer groups or non-governmental organizations [6]. In Ghana, farmer groups are gaining prominence in recent times while local and international non-governmental organizations with donor funding are helping smallholder farmers with extension services. Agricultural extension agents are central to any agricultural extension system and the quality of an extension system depends on the effectiveness of the agricultural extension agents. Available statistics indicate that the extension staff to farmer ratio in Ghana is about 1 extension agent to 1300 farmers, if all extension workers are deployed [9].

Notwithstanding the aforementioned challenges facing agricultural extension service delivery in many developing countries including Ghana, extension service remains an important factor for agricultural development and improvement of rural livelihoods. Agricultural extension is a form of informal education which is intended to help smallholders who are not literate to improve their living standards [10]. According to Swanson and Rajalahti [6], national agricultural development goals include maintaining national food security and improving rural livelihoods. These national goals seek to improve productivity of primary food crops, increase farm income, promote sustainable natural resource management practices, and organize farmers into producer groups. The national extension service provides key extension functions to achieve the national agricultural development goals. The extension functions include transfer of technology to farmers, training farmers to diversify their farming systems, use sustainable production methods, and form producer groups.

Extension delivery in Ghana has evolved and gone through several modifications in an effort to improve its effectiveness. The General Agricultural Extension Approach which was characterized by a top-down approach was replaced by the Unified Extension System (UES)<sup>3</sup> in 1978. The Travel and Visit (T&V)<sup>4</sup> system was part of the UES and was based on extension agents visiting farmers on their farms and providing training and information on modern technologies. However, poor coordination between the Department of Agricultural Extension Services and research institutions was identified due to their location in different ministries. The Decentralized Extension System was introduced in 1997 to address the shortcomings associated with the T&V system, especially with regard to its top-down approach [11,12]. The decentralization led to transfer of power from the Ministry of Food and Agriculture (MoFA)<sup>5</sup> to the district level offices at the District Assemblies, which represent the lowest level of government administration. The main reason for the decentralization was to develop a demand-driven extension system that has the ultimate goal of increasing the productivity and income of farmers.

Despite efforts to promote decentralization and local participation in extension program development, the extension system in Ghana has been criticized for not emphasizing decision making by farmers who are key stakeholders in extension, thus leading to general dissatisfaction with the extension system in the country [11,12]. In spite of the decentralization efforts, extension delivery in Ghana remains largely supply driven, with extension agents being assigned to designated operational (geographical) areas. Due to resource and logistical constraints, as well as a high extension agent to farmer ratio, access to extension is often influenced by how easily farmers can be reached. Farmer groups are also used as channels to reach farmers with extension messages and improved technologies.

The influence of agricultural extension on technology adoption is well documented in the existing literature. Wossen et al. [13] observed a positive and significant effect of agricultural extension on technology adoption in rural Nigeria while Mariano et al. [14] reported a positive influence of extension access on improved variety adoption in Tanzania and Ethiopia. In another study, Ghimire et al. [15] observed that extension access increased adoption of improved rice varieties in Central Nepal. Furthermore, Mignouna et al. [16] and Asfaw et al. [17] reported a significantly positive effect of agricultural extension on adoption of improved varieties in separate studies in Western Kenya and Philippines, respectively.

The income effect of agricultural extension is well documented in the extant literature. The income effect of agricultural extension has been recognized by Mwangi and Kariuki [18] in a study of smallholder farmers in developing countries.

<sup>3</sup> UES – Unified Extension System.

<sup>4</sup> T&V – Training and Visit.

<sup>5</sup> MoFA – Ministry of Food and Agriculture.

Danso-Abbeam et al. [19] reported an increase in farm income per hectare as well as total household income as a result of extension participation by maize farmers in northern Ghana. Also, Gebrehiwot [20] observed an increase in household income due to agricultural extension participation in Ethiopia. In another study, Asres et al. [21] noted an increase in household income as a result of Ethiopian farmers' participation in extension. Similar results were obtained by Davis et al. [22] in a study in East Africa. Through extension education, farmers acquire knowledge of modern production technologies to enhance productivity and farm income. In this study, it is assumed that access to agricultural extension will lead to increased adoption of improved seed technology which will translate into higher farm incomes.

The objectives of the study are twofold; first, to assess the effect of agricultural extension on improved seed technology adoption, and second, to estimate the effect of agricultural extension on farm income. The study employs a recursive bivariate probit model to evaluate the effect of extension on adoption and regression with endogenous treatment effect model to analyze the effect of extension on farm income.

## Materials and methods

### *Description of the study area and data collection*

The study was conducted in three districts in northern Ghana namely Kumbungu district in the Northern Region, and Bolgatanga Municipal and Kassena-Nankana district, both in the Upper East Region. The study area is characterized by savanna vegetation and a single rainfall regime. Temperatures are high throughout the year, reaching a peak of 40 °C in March–April. Agriculture is the main economic activity in the study area. Major crops grown in the area include maize, rice, yam, groundnut, and soybean. Majority of the farmers in the study area produce at subsistence level.

Multistage stratified random sampling was used to select farmers for the study. In the first stage, two regions were selected from northern Ghana, namely the Northern and Upper East Regions on the basis of importance in rice cultivation. At the time of the study, northern Ghana was made up of three administrative regions, which has been increased to five in 2019. Next, three districts were selected namely Kumbungu district in the Northern Region, and Bolgatanga Municipal and Kassena-Nankana district, both in the Upper East Region. Five communities were then selected from each district, followed by questionnaire administration to 20 farmers per community. This gave a total sample of 300 farmers.

### *Assessing the effect of agricultural extension on improved variety adoption*

The first objective of the study is to investigate the effect of agricultural extension on technology adoption, using a recursive bivariate probit model. The recursive bivariate probit model uses maximum-likelihood estimation to effectively estimate the effect of a binary regressor on a binary outcome when there are unobservable confounders. Typically, bivariate probit models are used to simultaneously estimate two binary outcomes which are influenced by the same explanatory variables. In situations where the two binary outcomes are influenced by slightly different explanatory variables, a seemingly unrelated bivariate probit model is typically used. However, in other situations, one of the dependent binary choice variables is also an explanatory variable in the other binary choice model. In this case, a recursive bivariate probit (RBP) model is used to jointly estimate the two models. In our case, we are interested in estimating the influence of access to extension (endogenous dichotomous variable) on the adoption of high yield varieties (dichotomous outcome variable). Our extension variable is most likely endogenous, and therefore we chose the simultaneous recursive bivariate model in the presence of endogeneity as the model to apply [see 23]. We apply the simultaneous likelihood estimation, which is more efficient than the two-stage instrumental variable (IV) procedure [24].

For identification, it is usually assumed that the exclusion restriction holds also in the RBMs with endogenous variables [23]. Wilde [25] has noted that identification in the recursive binary variable probit model does not require additional instrumental variables (IVs) in the reduced form equation, but in this case the identification relies on the functional form, i.e. normality of the stochastic disturbances as a standard case. Marra and Radice [26] have suggested semiparametric approach for the estimation strategy, which seems to work also without instruments because there is flexibility in functional specification.

The recursive bivariate probit model is derived as follows. The two binary variables, namely participation in agricultural extension and adoption of improved varieties can be represented as  $Z_1$  and  $Z_2$ . The two probit models can be specified using an index function, with latent continuous variables  $Z_1^*$  and  $Z_2^*$  for extension participation and adoption decision, respectively, following Maddala [27].

$$Z_{1i}^* = x_{1i}\beta_{1i} + e_{1i} \quad (1)$$

$$Z_{1i} = \begin{cases} 1, & \text{if } Z_{1i}^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

where  $Z_1$  is the observed extension variable,  $x_1$  is a vector of independent variables influencing participation in agricultural extension,  $\beta_1$  is a vector of parameters to be estimated, and  $e_1$  is the random error term.

Similarly,

$$Z_{2i}^* = \partial Z_{1i} + x_{2i}\beta_{2i} + e_{2i} \quad (3)$$

$$Z_{2i} = \begin{cases} 1, & \text{if } Z_{2i}^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

where  $Z_2$  is the observed adoption variable,  $x_2$  is a vector of independent variables explaining adoption decisions of farmers,  $\beta_2$  is a vector of parameters to be estimated, and  $e_2$  is the random error term.  $Z_{1i}$  enters Eq. (3) as a dummy variable and measures the effect of extension on adoption, which is captured by  $\partial$ .

There is dependence between the error terms in Eqs. (1) and (2). The two error terms have the following bivariate standard normal distribution with correlation  $\zeta$  such that

$$E[e_1] = E[e_2] = 0, \text{var}[e_1] = \text{var}[e_2] = 1 \text{ and } \text{corr}[e_1, e_2] = \zeta \quad (5)$$

#### Assessing the effect of agricultural extension on farm income

The second objective of the study is to assess the effect of agricultural extension on farm income. This objective is premised on the assumption that extension enhances farm income. A methodological challenge with this estimation is the sample selection problem, since farmers may self-select into agricultural extension program or may have innate abilities that correlate with farm income. In order to deal with the sample selection problem, the study used an endogenous treatment effect model to assess the effect of agricultural extension on farm income. The regression with endogenous treatment effect model (RETEM) corrects for both observable and unobservable biases resulting from nonrandom assignment of respondents into agricultural extension, hence providing unbiased estimate of the impact of extension on farm income. The endogenous treatment effect model estimates the average treatment effect of agricultural extension on the outcome variable (that is, farm income). In other words, the RETEM measures the pure effect of agricultural extension on farm income of participants in extension.

The RETEM estimates the average treatment effect (ATE)<sup>6</sup> and other parameters of a linear regression model that includes an endogenous dummy variable. The RETEM uses a linear model for the outcome equation while a normal distribution is used to model the deviation from the conditional independence assumption that is imposed by the estimator. The model allows for a specific correlations structure between the unobservables associated with the treatment as well as the unobservables associated with the potential outcomes. Heckman [28,29] introduced this model into the extant literature while Maddala [23] derived the maximum-likelihood and control function estimators of the model. Authors such as Cameron and Trivedi [30] and Wooldridge [24] describe the model as an endogenous treatment-effect model and connect it to recent work.

The regression with endogenous treatment effect model is derived as follows. Suppose we represent the dependent continuous farm income variable by  $Y$  and the endogenous dichotomous extension variable by  $Z_1$  (as previously defined), then the regression with endogenous treatment effect model can be presented as follows:

$$Y_i = X_i\beta + \delta Z_{1i} + v_i \quad (6)$$

$$Z_{1i}^* = w_i\gamma + u_i \quad (7)$$

$$Z_{1i} = \begin{cases} 1, & \text{if } Z_{1i}^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

where  $Z_1^*$  is the latent adoption variable measuring the probability of adoption,  $Z_1$  is the endogenous dichotomous adoption variable which assumes a value of 1 for adopters and 0 for nonadopters.  $X_i$  and  $w_i$  are explanatory variables for the farm income and extension equations, respectively, while  $\beta$  and  $\gamma$  are parameters to be estimated. Maximum likelihood estimation was used to estimate the parameters of the linear regression with endogenous treatment effect model.

## Results and discussion

### Description of the sample

Most of the respondents (78%) were male, and have an average farm income of GH¢ 1829 and household size of 10 members (Table 1). Typically, smallholder farm families in developing countries such as Ghana tend to have large household size which serves as a source of agricultural labor. The average age of the respondents was 41 years and they possessed 4 years of formal education. The results indicate that the respondents are in the active working age but do not possess sufficient formal education. This calls for other means of increasing farmers' knowledge and literacy such as informal educational programs, farmer-field schools, extension education, among others.

<sup>6</sup> ATE – Average treatment effect.

**Table 1**

Definition of variables and summary statistics.

Variable	Definition	Mean	S.D.
Farm income	Income from rice farming in Ghana cedis <sup>†</sup>	1829	1600
Sex	Sex of farmer: 1 = male, 0 otherwise	0.78	0.41
Age	Age of respondent in years	41.2	12.3
Education	Years of formal education of respondent	3.93	5.35
Household size	Number of household members	9.65	7.20
Production system	Production system: 1 = irrigation, 0 otherwise	0.50	0.50
Group membership	Farmer group membership: 1 = member, 0 otherwise	0.66	0.47
Herd ownership	Herd ownership: 1 = herd owned, 0 otherwise	0.34	0.47
Credit access	Access to credit: 1 = access, 0 otherwise	0.40	0.49
Adoption	Improved variety adoption: 1 = adopter, 0 otherwise	0.67	0.47
Mechanization	Adopt mechanization: 1 = adopter, 0 otherwise	0.65	0.48
Extension	Access to extension: 1 = access, 0 otherwise	0.63	0.48
Regional dummy	Regional dummy: 1 = Northern, 0 otherwise	0.33	0.47
Farm size	Rice farm size in hectares	0.86	0.68

<sup>†</sup> 1 Ghana cedi (GHe) = US\$0.20.**Table 2**

Characteristics of respondents according to adoption status and access to extension.

Variable	Adoption of improved varieties				Access to agricultural extension			
	Adopters (N = 200)		Non-adopters (N = 100)		Access (N = 190)		No access (N = 110)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Adoption					0.616	0.488	0.755	0.432
Extension	0.585	0.494	0.730	0.446				
Farm income	1917	1621	1651	1552	1823	1696	1839	1428
Sex	0.830	0.377	0.690	0.465	0.742	0.439	0.855	0.354
Age	42.32	12.69	38.98	11.25	42.07	11.93	39.71	12.85
Education	3.970	5.364	3.860	5.349	3.979	5.385	3.855	5.314
Household size	9.350	6.753	10.25	8.033	8.968	6.751	10.83	7.819
Production system	0.535	0.500	0.430	0.498	0.579	0.495	0.364	0.483
Group membership	0.650	0.478	0.680	0.469	0.774	0.420	0.464	0.501
Herd ownership	0.340	0.475	0.330	0.473	0.384	0.488	0.255	0.438
Credit access	0.355	0.480	0.500	0.503	0.458	0.500	0.309	0.464
Regional dummy	0.380	0.487	0.240	0.429	0.221	0.416	0.527	0.502
Farm size	0.880	0.656	0.811	0.733	0.854	0.741	0.862	0.568
Mechanization	0.745	0.437	0.460	0.501	0.647	0.479	0.655	0.478

S.D. means standard deviation.

The respondents have an average farm size of less than 1 hectare, suggesting that landholdings are very small. Most smallholder farmers are generally poor and do not have large landholdings, and therefore tend to cultivate small areas. Some smallholder farmers also cultivate small areas due to limited access to credit for farm expansion. The limited access to credit is supported by the fact that 40% of the respondents use credit in production. In terms of herd ownership and group membership, 34% and 66% respectively have cattle and belong to a farmer organization. Households owning cattle are expected to be wealthier, better adopters and more likely to receive extension visits. This is because access to services in most rural communities is usually affected by social influence, such as wealth and social position. In addition, 65% of the respondents use mechanization in farming. The use of mechanization entails the use of tractor for ploughing and land preparation. Adoption of improved varieties is expected to correlate positively with farm mechanization. Furthermore, access to extension is anticipated to enhance adoption of improved varieties. Sixty-seven (67) percent of the respondents cultivated improved varieties. In addition, 50% of the respondents were irrigation users while 33% are located in the Northern Region. The number of extension visits is on average 3 for the cropping season while 36.7% of the farmers were not visited at all. The number of visits is partially limited due to inadequate number of extension agents [9].

The characteristics of the respondents according to adoption status and access to extension are presented in Table 2.

Adopters of improved varieties had higher farm income than non-adopters whereas farm income was marginally higher for farmers without access to extension compared to those with extension contact. The result supports the notion that adoption correlates positively with farm output and productivity, thereby improving farm income. Also, a higher proportion of those who received extension visits used credit in farming compared to those without extension access. The result is plausible because extension agents facilitate farmers' access to credit in rural communities. Extension agents do this by facilitating the formation of farmer groups which serve as social collateral and medium for credit delivery to rural farmers. Access to credit is however lower for adopters of improved varieties as compared to non-adopters. The result does not lend itself to easy interpretation and may suggest the likelihood of credit market imperfections. Adopters as well as respondents with



**Table 3**

Recursive bivariate probit analysis of the effect of agricultural extension on adoption.

Variable	Adoption of improved varieties			Access to agricultural extension		
	Coefficient	S. E.	P-value	Coefficient	S. E.	P-value
Sex	0.610***	0.204	0.003	−0.478**	0.227	0.035
Age	0.011*	0.006	0.051	0.007	0.006	0.219
Education	0.105**	0.041	0.010	−0.092**	0.042	0.030
Household size	−0.023*	0.012	0.050	−0.034***	0.012	0.005
Farm size	−0.053	0.119	0.657	0.254**	0.124	0.040
Education*Sex	−0.119***	0.043	0.006	0.112**	0.044	0.011
Production system	−0.031	0.145	0.831	0.523***	0.160	0.001
Group membership	−0.560***	0.151	0.000	0.910***	0.166	0.000
Herd ownership	0.035	0.152	0.819	0.333**	0.167	0.046
Regional dummy	0.914***	0.187	0.000	−0.860***	0.199	0.000
Access to extension	1.336***	0.099	0.000			
Constant	−1.141***	0.320	0.000	−0.177	0.333	0.594
Log-likelihood	−320.6					
Wald test $\chi^2$ (21)	227.02***					

S.E. means standard error. LR test of independent equations:  $\chi^2$  (1) = 6.80\*\*\*. \*\*\* 1% significance level; \*\* 5% significance level; \*10% significance level.

access to extension have relatively higher education than non-adopters and those without extension contacts, respectively. This suggests a positive influence of education on adoption and extension access, which is in line with *a priori* expectation. Furthermore, the use of irrigation was higher among adopters compared to non-adopters. Irrigation therefore positively correlates with adoption. Similarly, irrigation use is higher for those with access to extension compared to those without access. This result is consistent with *a priori* expectation because irrigation users usually belong to water users' associations which can facilitate access to extension services. Also, a greater proportion of adopters used mechanization compared to non-adopters, while adopters have larger farms compared to non-adopters. Contrary to expectation, access to extension was higher for non-adopters.

#### The effect of agricultural extension on adoption

The first objective of the study sought to determine the effect of agricultural extension on adoption of improved maize varieties by farmers in the Tolon District of northern Ghana. A recursive bivariate probit model was estimated to evaluate the effect of agricultural extension on adoption. The estimation also provided estimates of other covariates that are significantly related to improved variety adoption and access to extension. The results are presented in Table 3. The test of independence of the adoption and extension participation equations indicate that the two equations are related as shown by the statistical significance of the likelihood ratio test at 1% level.

The results indicate a positive and significant influence of agricultural extension on improved variety adoption at less than 0.1% risk level. The result is consistent with *a priori* expectation as extension agents are the primary means by which smallholders receive information on modern production practices and innovations. Through extension contacts, farmers learn about improved technologies that enhance productivity and farm income. The result of the study agrees with Mabe et al. [31] in their study on improved rice variety adoption in the Volta Region of Ghana. Similarly, Wossen et al. [13] indicated a positive relationship between extension and adoption of improved cassava varieties by farmers in rural Nigeria. The result is also consistent with the findings of Asante et al. [32] in their study on adoption of yam minisett technology in Ghana as well as that of Walisinghe et al. [33] in their study on technology adoption in Sri Lanka. Other studies that corroborate the finding of this study include Ghimire et al. [13] in their study involving rice farmers in Central Nepal and Rahman et al. [34] in their study on adoption of improved pulse production technologies in Bangladesh.

The result of the RBP model also provided estimates of other covariates that are significantly related to adoption of improved varieties. With regards to gender, male farmers have a higher likelihood to adopt improved varieties than their female counterparts. This result is in agreement with *a priori* expectation because men usually have greater control over productive resources in most rural communities. Since most women do not have control over productive resources in the household, they are more likely to cultivate traditional varieties which may not require expensive external inputs and are better adapted to the local conditions, even though they may give lower yield. The results of this study are consistent with the findings of Akumbole et al. [35] in their study on the determinants of adoption of improved maize technology in Bawku West District of Ghana.

Furthermore, adoption of improved varieties increased with age of the farmer, suggesting that older farmers are more likely to adopt improved varieties than younger farmers. Older farmers may be more experienced in farming and may have gained knowledge of production practices that enhance productivity. This result is contrary to the view that older farmers are more reluctant to change their production practices while younger farmers are more adventurous and hence more likely to choose improved varieties. Yimer et al. [36] observed a negative relationship between age and adoption of improved

wheat seed but found a positive association in the case of fava bean adoption by farmers in Ethiopia. The result also agrees with the findings of Mabe et al. [31] in their study on improved rice variety adoption in the Volta Region of Ghana as well as Asante et al. [32] in their study on adoption of yam miniset technology across various agro-ecological zones of Ghana.

The study also indicates that adoption of improved varieties increases with education of the farmer. The education variable is positive and significant at 5% level. The result is expected because education enhances the ability of farmers to make informed decisions that lead to productivity growth. Education improves the human capital and decision making which is expected to enhance technology adoption. Mabe et al. [31] obtained a similar result in their study on improved rice variety adoption in the Volta Region of Ghana. The result is also consistent with the findings of Ghimire et al. [15] in their study involving rice farmers in Central Nepal as well as Rahman et al. [34] in their study on adoption of improved pulse production technologies in Bangladesh.

Household size was inversely related to adoption implying that an increase in household members, which is a proxy for labor availability, was associated with lower adoption of improved varieties. The result is contrary to expectation because improved variety adoption is expected to lead to higher labor demand which can be provided by larger households, all things being equal. Smaller households are expected to be more labor-constrained, hence less likely to adopt improved varieties. The result is consistent with the findings of Yimer et al. [36] in their study on the impact of adoption of improved wheat and fava bean seeds on productivity in Ethiopia but varies with Akumbole et al. [35] in their study on improved maize technology adoption in Bawku West District of Ghana.

Furthermore, membership in a farmer group was negatively related to adoption of improved rice varieties, which is contrary to *a priori* expectation. This is because farmer groups are recognized as channels for the dissemination of information to rural farmers, hence they are expected to enhance smallholders' knowledge of improved technologies leading to higher adoption. The result of this study varies with the findings of Nkegbe et al. [37] in their study on adoption of soil and water conservation practices in Northern Ghana as well as Abdulai et al. [38] in their study on adoption of improved rice technologies in Sagnarigu District of Ghana.

The regional dummy variable was statistically significant at 1% level. The result implies that producers in the Northern Region are more likely to adopt improved varieties compared to those in the Upper East Region. The reasons for the difference across the two regions are hard to explain. However, the Northern Region is more endowed with fertile agricultural land and has a greater agricultural potential than the Upper East Region.

Finally, the interaction of education and sex of the farmer indicates that educated female farmers have a higher propensity to adopt improved varieties compared to educated male farmers. This implies that education enhances adoption of improved varieties by female farmers more than it does for their male counterparts. The result supports the call for measures to enhance the education of women in the country who according to national statistics fall behind men in educational attainment, but constitute a higher percentage of the population and contribute immensely to the nation's agricultural labor force.

The recursive bivariate probit model also provided estimates of covariates that are significantly related to access to agricultural extension. For example, access to agricultural extension correlates negatively with sex of the farmer, implying that women have higher participation in agricultural extension in the study area. Emmanuel et al. [39] however observed that male farmers in Ghana were more likely to receive extension visits. The result also reveals a negative correlation between access to agricultural extension and education of the farmer, which is contrary to expectation. The expectation is that an increase in the years of formal education will correlate with higher participation in agricultural extension because education enhances farmers ability to seek information and services that enhance their farming activities. The result of this study is contrary to the finding of Wossen et al. [13] in their study in Nigeria. In Ghana, extension service is not so much demand driven, as it is seen as a public good/service. Hence, education may play a little role in access to extension. For example, extension agents working in rural communities are likely to target poorer, uneducated farmers in an effort to improve their level of production.

Furthermore, there was a negative and significant correlation at 1% level between extension access and household size, indicating that smaller households are more likely to participate in agricultural extension. With regards to ownership of cattle, which is a proxy for wealth status, the study posited a positive and significant association with extension access at 5% level. The result suggests that wealthier households are more likely to receive extension visits, which is consistent with *a priori* expectation.

The results further indicate that farm size is positively associated with extension access and significant at 5% level. This implies that farmers with larger farms are more likely to have access to agricultural extension, which is consistent with *a priori* expectation. The result is in consonance with the findings of Danso-Abbeam et al. [19] which showed that extension access increased with farm size allocated to maize production in northern Ghana. Emmanuel et al. [39] also observed a similar result in their study involving rice farmers in the northern part of Ghana. Similarly, Gebregziabher and Holden [40] observed a positive relationship between farm size and extension participation in Ethiopia. Access to agricultural extension was positively related to landholding in Pakistan [41]. The result of this study is however contrary to the finding of Wossen et al. [13] in their study in Nigeria.

The production system (whether an irrigation user or not), was significantly associated with access to extension. The result implies that farmers who use irrigation are more likely to have access to extension. A possible explanation for this result is that irrigation users usually form irrigation water users' association which is expected to facilitate access to services such as agricultural extension. In addition, the results of the study indicate that farmers who belong to a farmer group are



**Table 4**

Effect of agricultural extension on farm income as determined using the endogenous treatment effect model.

Variable	Farm income model			Access to agricultural extension		
	Coefficient	S. E.	P-value	Coefficient	S. E.	P-value
Sex	639.3***	235.4	0.007	-0.468*	0.260	0.072
Age	-2.195	6.422	0.733	0.007	0.007	0.346
Education	37.31	47.06	0.428	-0.100**	0.050	0.045
Household size	26.26**	13.20	0.047	-0.024*	0.014	0.082
Production system	626.7***	170.6	0.000	0.545***	0.178	0.002
Group membership	-75.21	213.7	0.725	1.023***	0.181	0.000
Herd ownership	452.1***	168.9	0.007	0.287	0.206	0.164
Regional dummy	749.8***	247.6	0.002	-1.006***	0.219	0.000
Farm size	714.2***	136.2	0.000	0.223	0.141	0.114
Education*Sex	-52.34	50.20	0.297	0.121**	0.052	0.021
Access to credit	315.9**	153.1	0.039			
Access to extension	916.3**	444.9	0.039			
Constant	-782.4*	402.7	0.052	-0.161	0.376	0.668
/athrho	-0.553**	0.225	0.014			
/lnsigma	7.163***	0.065	0.000			
rho	-0.503	0.168				
Sigma	1291	84.09				
Lambda	-649.0	251.4				
Log-likelihood	-2705.2					
Wald test $\chi^2$ (12)	203.16***					
LR test of independent equations: $\chi^2$ (1) = 3.15*						

S.E. means standard error. \*\*\* 1% significance level; \*\* 5% significance level; \*10% significance level.

more likely to have access to extension services, which is consistent with a priori expectation. In recent times, farmers associations have been recognized as cost-effective means to disseminate information and technology to farmers. Hence, farmer groups have become important channels for agricultural extension delivery to many rural farmers. The result agrees with Danso-Abbeam et al. [19] who found participation in agricultural extension to increase with farmer group membership in northern Ghana. Similar results were obtained by Abdallah and Abdul-Rahaman [42] in a study assessing the determinants of extension access among smallholder women farmers in northern Ghana.

Furthermore, the study found a negative and statistically significant relationship between the regional dummy variable and access to extension. This implies that farmers in the Northern Region are less likely to have access to extension service compared to farmers in the Upper East Region. No ready explanation can be found for this result. However, the Northern Region has a higher population of farmers than the Upper East Region and covers a wider geographical area, which may have implication for extension access. Finally, the interaction of education and gender of the farmer was positive and significant at 5% level, indicating that educated male farmers are more likely to receive extension visits compared to educated female farmers. Thus, education enhances access to extension of men more than women farmers.

#### Effect of agricultural extension on farm income

The second objective of the study sought to estimate the effect of agricultural extension on farm income using the endogenous treatment effect model (Table 4). The test of independence of the farm income and extension participation equations indicate that the two equations are related as shown by the statistical significance of the likelihood ratio test at 10% level.

The results indicate that participation in agricultural extension enhances farm income of participants in agricultural extension by GH¢916.3, which is significant at 5% level. The result justifies government investment in agricultural extension services to farmers and the need to increase access to extension services especially for smallholder farmers. The result agrees with Danso-Abbeam et al. [19] who observed an increase in farm income per hectare as a result of extension participation in northern Ghana. The authors also found that total household income increased with extension participation.

Apart from the impact parameter, the RETEM also provided estimates of other parameters of the farm income equation. The results indicate that farm income increases with household size. Household size provides an indication of labor supply, hence an increase in household size suggests availability of labor to carry out critical farm operations. The result is consistent with the findings of Ibekwe et al. [43] in their study in Nigeria as well as that of Bongole [44] in a study assessing the determinants of farm income in Tanzania. A similar result was obtained by Kolleh [45] in a study in Liberia.

The results of the study indicate that male farmers obtained higher income from farming compared to their female counterparts. The result is consistent with a priori expectation because men usually have greater ownership and control over production resources and assets in most rural communities in Ghana. Women also play many roles in the household

apart from farming which reduce their time allocation to farming and hence their level of income from agriculture. Women's multiple roles include daily household chores, petty trading, taking care of children, among others. The result of the study agrees with Ahmed and Anang [46] in their study involving maize farmers in Tolon District of Ghana. In a study involving cooperative members and non-members in Liberia, Kolleh [45] observed that male farmers were more likely to obtain higher farm incomes even if they did not participate in farmer cooperatives.

Farm income increased with access to irrigation which is consistent with *a priori* expectation. Irrigation ensures intensification of resource use and all-year-round crop production which may enhance productivity and income. By removing production risks associated with erratic rainfall, irrigation may encourage farm investment and input intensification, while enhancing crop growth and productivity. The results are in agreement with the findings of Qasim and Knerr [47] in a study involving rain-fed wheat-producing farm households in Pakistan. Smith et al. [48] also observed a positive relationship between irrigation access and agricultural income in their study in Uganda.

Herd ownership positively correlated with farm income at 1% significance level. Herd ownership is a measure of wealth; hence herd owners may be able to finance input purchases and increase production to enhance income from farming. Furthermore, herd owners could benefit from the use of animal traction in production to increase productivity and income from farming. In addition, herd owners may be able to apply manure from cattle production on their farms to enhance soil fertility and crop yield. The result of the study agrees with Ahmed and Anang [46] who observed a positive relationship between herd ownership and farm income of maize producers in Tolon District of Ghana.

The results further indicate that farm income increases with farm size (cultivated area) at 1% significance level. The result agrees with the findings of Bayissa [49] which indicated a positive relationship between farm size and household income in Malawi. Mafimisebi [50] also observed a positive association between farm size and farm income in a study involving cassava farmers in Ondo State, Nigeria. Farmers with larger farms can invest more resources into the farm business to increase farm income relative to land-scarce farmers. Hence, the larger the farm, the higher the farm income, all other things being equal. Ahmed and Anang [46] obtained a similar result in their study involving maize producers in Tolon District of Ghana. The result is however contrary to the finding of Qasim and Knerr [47] in their study involving wheat producers in Pakistan.

Consistent with *a priori* expectation, farm income increased with access to credit. There is increasing recognition of the important role agricultural credit plays in increasing productivity and farm income of resource-poor farmers in developing countries such as Ghana. Agricultural credit enables timely acquisition and optimum utilization of farm inputs to achieve optimum yield thereby enhancing farm income. The result of this study agrees with Kolleh [45] who observed that access to credit enhanced farm income of cooperative participants in Liberia.

The location dummy variable was significant at 1% level, indicating that farmers in the Northern Region have higher farm income than those in the Upper East Region. The Northern Region is more endowed with agricultural land which is expected to enhance agricultural production resulting in higher farm incomes.

For the extension model, the significant covariates in the regression with endogenous treatment effect model (RETEM) and the recursive bivariate probit model (RBP) model are similar except that the farm size and herd ownership variables did not show statistical significance in the RETEM as was the case with the RBP model (both variables were significant at 5% level). The results are therefore not discussed in this section to avoid repetition.

## Conclusions

The study assessed the effect of agricultural extension on improved seed technology adoption and farm income in northern Ghana. The data for the study came from a farm household survey conducted in two regions of northern Ghana. The results indicated positively significant adoption and income effects of agricultural extension. Ensuring farmers' access to agricultural extension is therefore essential to technology adoption and increase in farm income of smallholder farmers in northern Ghana. Access to agricultural extension was low despite the positive adoption and income effects of extension. Effective measures are therefore required to improve outreach and accessibility to agricultural extension services to ensure that the country achieves the goal of increasing productivity and farm income of smallholder agrarian households. Efforts to increase access to agricultural extension should focus on strengthening farmer-based organizations, which are important channels for extension delivery and information dissemination. Institutional factors such as provision of agricultural credit, access to irrigation technology and agricultural extension enhance farm income, hence efforts are required to make these available to farmers.

## Declaration of Competing Interest

Authors declare no competing interest in relation to this research.

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